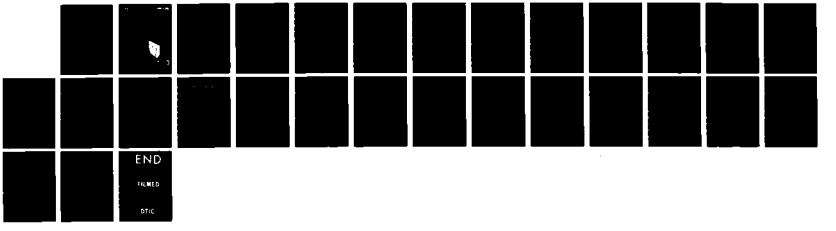
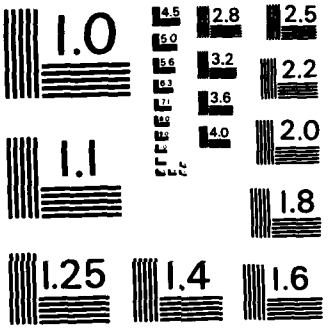
AD-A159 748 FORT ERWIN CALIFORNIA FAMILY HOUSING COMPARISON TEST: 1/1
OPERATION AND MAINT..(U) CONSTRUCTION ENGINEERING
RESEARCH LAB (ARMY) CHAMPAIGN IL R D NEATHAMMER AUG 85
UNCLASSIFIED CERL-IR-P-85/14 F/G 5/11 NL





US Army Corps
of Engineers
Construction Engineering
Research Laboratory

USA-CERL

INTERIM REPORT P-85/14
August 1985

Fort Irwin, CA, Family Housing Comparison Test: Operation and Maintenance Costs of Manufactured vs. Conventionally Built Units

by
Robert D. Neathammer

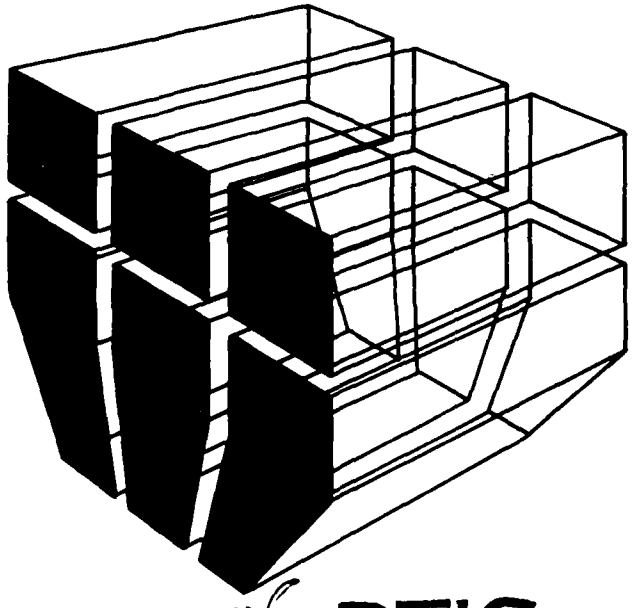
Congress directed the construction of 200 units of manufactured/factory-built housing at Fort Irwin, CA, in 1982 to see if this method of construction will cost less than conventional housing, yet still provide durable housing commensurate with contemporary housing standards.

Congress directed the Department of Defense (DOD) to conduct a study to compare the operation and maintenance (O&M) costs of manufactured housing and conventional housing. DOD will report to Congressional committees on the conditions and parameters under which this test was conducted and the results of the test after it is completed in FY88.

To compare these two types of construction properly, DOD must be able to identify O&M costs and user satisfaction reliably. In addition, it must be able to identify differences in O&M costs and the reasons for those differences.

This report is the first of four interim reports on the progress of the study. A yearly summary will be provided by USA-CERL for each of FY84-FY87. A final report covering the first 5 years of O&M costs will be written at the end of FY88.

No conclusions or inferences should be made as to which type of construction was lowest cost until the final 5-year summary is complete.



The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official indorsement or approval of the use of such commercial products. The findings of this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

DESTROY THIS REPORT WHEN IT IS NO LONGER NEEDED
DO NOT RETURN IT TO THE ORIGINATOR

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER IR P-85/14	2. GOVT ACCESSION NO. AD-A159 740	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) FORT IRWIN, CA, FAMILY HOUSING COMPARISON TEST: OPERATION AND MAINTENANCE COSTS OF MANUFACTURED VS. CONVENTIONALLY BUILT UNITS		5. TYPE OF REPORT & PERIOD COVERED Interim 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Robert D. Neathammer		8. CONTRACT OR GRANT NUMBER(s) IAOs R039 FHAA022-83
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Construction Engr Research Laboratory P.O. Box 4005 Champaign, IL 61820-1305		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE August 1985 13. NUMBER OF PAGES 25
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Copies are available from the National Technical Information Service
Springfield, VA 22161

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Fort Irwin, CA
housing projects
operation and maintenance
cost analysis
prefabricated buildings

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Congress directed the construction of 200 units of manufactured/factory-built housing at Fort Irwin, CA, in 1982 to see if this method of construction will cost less than conventional housing, yet still provide durable housing commensurate with contemporary housing standards.

Congress directed the Department of Defense (DOD) to conduct a study to compare the operation and maintenance (O&M) costs of manufactured housing and conventional housing. DOD will report to Congressional committees on the conditions and parameters

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

BLOCK 20 (Continued)

under which this test was conducted and the results of the test after it is completed in FY88.

To compare these two types of construction properly, DOD must be able to identify O&M costs and user satisfaction reliably. In addition, it must be able to identify differences in O&M costs and the reasons for those differences.

This report is the first of four interim reports on the progress of the study. A yearly summary will be provided by USA-CERL for each of FY84-FY87. A final report covering the first 5 years of O&M costs will be written at the end of FY88.

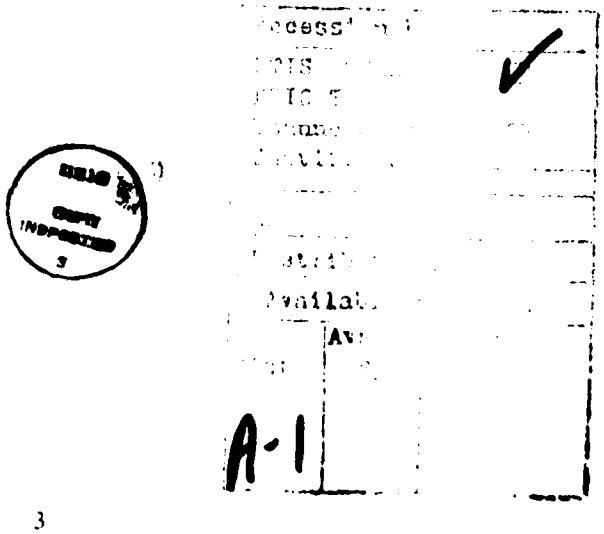
No conclusions or inferences should be made as to which type of construction was lowest cost until the final 5-year summary is complete.

FOREWORD

This research was conducted for the Assistant Chief of Engineers, Office of the Chief of Engineers (OCE) under IAOs from Fort Irwin and Headquarters, U.S. Army Forces Command (FORSCOM HQ), dated 22 Aug 83, 19 Sep 83, and 14 May 84. The OCE Technical Monitor was Mr. Alex Houtzager, DAEN-ZCH-F.

The work was performed by the Facility Systems Division (FS), U.S. Army Construction Engineering Research Laboratory (USA-CERL). The Principal Investigator was Mr. Robert Neathammer. Assistance was provided by Mr. Robert Doerr, Mr. Thomas Napier, Ms. Mary Chionis, Mr. William Dolan, Mr. John Shonder, Mr. Victor Storm, and Ms. Darcy Weber. Mr. E. A. Lotz is Chief of USA-CERL-FS.

COL Paul J. Theuer is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.



CONTENTS

FORT IRWIN, CA, FAMILY HOUSING COMPARISON TEST: OPERATION AND MAINTENANCE COSTS OF MANUFACTURED VS. CONVENTIONALLY BUILT UNITS

1 INTRODUCTION

Background

Congress believes that use of manufactured (factory built) military housing, rather than conventionally built units, may result in lower overall costs, but still provide durable housing that meets contemporary housing standards. To verify this belief, Congress directed the Department of Defense (DOD) to construct 200 units of manufactured housing at Fort Irwin, CA, for comparison with conventionally built housing.[1]

The manufactured units were to be constructed to meet DOD standards and criteria for essential space, structural durability, energy efficiency, material quality, and life safety. These standards and criteria are compatible with, and complementary to, the Federal Manufactured Housing Construction and Safety Standards (FMHCSS). The Fort Irwin study will compare the impact of the FMHCSS versus standard DOD criteria, except for the essential criteria listed above.

The study will be conducted during the first 5 years the housing units are occupied; initial occupancy on some units began in December 1983. The study will compare 200 two-bedroom manufactured housing units (MHU) to 144 two-bedroom, conventionally built units (CBU). DOD will present the conditions and parameters of this test to Congress and will report the study results at the end of each year of the test.

To properly compare manufactured versus conventional housing, the study must address operation and maintenance (O&M) costs and user satisfaction for both types of housing. The study should not only identify the differences, if any, in O&M costs, but also identify the reason for the differences and their importance for future construction criteria, construction methods, and occupant satisfaction.

[1] Report No. 97-44, *Military Construction Authorization Act* (House of Representatives Committee on Armed Services, 1982), pp 8-9.

Objective

The objective of this report is to present results of the O&M analysis, of whole house energy tests, and of occupant satisfaction through September 1984.

Scope

This report addresses O&M costs and occupant satisfaction for both conventionally built and manufactured housing from construction through September 1984.

Approach

The first step in the project was to develop data collection and data analysis procedures. The cost comparisons and analyses which will be done in this study were established in USA-CERL Special Report P-140, *Fort Irwin Housing Comparison Test*.[2] The data will be collected, summarized, and reported on a yearly basis.

2 DESCRIPTION OF THE FAMILY HOUSING UNITS

Manufactured Housing Units (MHU)

These 200 units consist of 50 two-story fourplexes. Each upper unit has a balcony-porch and each lower one has a patio with privacy fencing. Each unit has a refrigerator, range, garbage disposal, and central air conditioning. Each unit has two bedrooms, a kitchen, living-dining area, one bathroom, and a one-car garage. There are two units on each level.

Initial occupancy was:

61 units	Dec 83
7 units	Jan 84
64 units	Feb 84
57 units	Apr 84
9 units	May 84
2 units	Jun 84

Conventionally Built Units (CBU)

The 144 units consist of 13 sixplexes, 6 fiveplexes, and 9 fourplexes, all two-story buildings. Each unit has two bedrooms. The fourplexes have two units on each level. There are two units on the second story in

[2] M. J. O'Connor, *Fort Irwin Housing Comparison Test*, Special Report P-140/ADA130349 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], February 1983).

the five- and sixplexes with the additional unit(s) on the first level. The CBU also have a one-car garage, refrigerator, range, garbage disposal, and central air conditioning.

A detailed description of all units can be found in the Los Angeles District Office report.[3]

Initial occupany was:

8 units	Feb 83
28 units	Mar 83
38 units	Apr 83
31 units	May 83
23 units	Jun 83
14 units	Jul 83
2 units	Aug 83

3 DATA COLLECTION PROCEDURES

Data that should be collected in this study and their level of detail were discussed in USA-CERL SR P-140. That report emphasized that data be collected at such a level of detail that any differences found between the two types of construction could be explained. Appendix A lists the housing units and their identification numbers used in the data collection.

Data Collection

Discussions were held with the technical monitor, Facilities Engineering Support Agency (FESA) representatives, the FORSCOM HQ representative, Fort Irwin Personnel, and the base operations contractor, Boeing Services Inc. (BSI) representatives to determine best methods of collecting the data. For O&M data, USA-CERL designed report forms (Appendix B). BSI was contracted to segregate all service orders for maintenance for the test units and report cost data to USA-CERL through the Fort Irwin Directorate of Engineering and Housing (DEH) on a monthly basis.

BSI was contracted to read gas and electric meters at the end of each month and report similarly.

Self-help data reports* and occupany data were to be forwarded quarterly.

An occupant satisfaction questionnaire (Appendix F) is given to each vacating family with a mail-back envelope to USA-CERL.

Data Verification

USA-CERL is verifying the reported data several ways. Each service order is checked against the reported data forwarded by BSI. Discrepancies are resolved on verification vists to Fort Irwin. Additionally, BSI has set up separate accounting codes for the two groups of units and the total billed is compared to the total obtained from summing over all the individual service order data.

On meter readings, USA-CERL developed a computer program to compare monthly readings. When apparently erroneous data occurs, BSI is notified and corrections are made.

Data Analysis

Maintenance Costs

These costs are reported on a unit-month basis and yearly basis. In future reports they will be on a unit-year basis. The data will also be summarized by building component to determine if one or more components for one of the types of units is the cause of large maintenance costs. If so, an effort will be made to determine why these costs occur, i.e., what criteria or design features should be reviewed/changed.

Cost differences will probably be caused by material quality and/or installation, differences inherent to manufactured or conventional construction, and possible errors in specifications for the two projects.

Warranty work referred to the construction contractor will not be included in the cost comparison since no cost data are available or applicable, as it is not a cost to the government.

Energy Consumption

Gas and electricity consumption will be reported on a unit-month basis and a yearly basis. Since most of the MHU were not completed until April 1984, prior energy consumption data for the CBU will not be used in comparisons. Energy consumption comparisons

[3] *Fort Irwin Family Housing Study: A Report on Manufactured/Factory-Built Housing and Site-Built Housing, Fort Irwin, CA* (U.S. Army Corps of Engineers, Los Angeles District, September 1984).

*Self-help is a program whereby occupants obtain supplies and materials from a central warehouse to make minor repairs themselves.

are only valid for the same time frame because of varying weather conditions.

Occupancy Effects

Occupancy data are also being collected. These data will be analyzed to ensure that both types of units have a similar distribution of occupants during the 5 years (ages, numbers). If required, these data will be correlated with O&M costs to help explain differences in costs.

Self-Help Data

These data will be summarized to see if maintenance costs are affected.

Occupant Satisfaction

Questionnaires are given to vacating occupants. Additionally, special surveys will be done periodically on occupants who have resided in the units for 1 to 2 years. Comparisons will be made to determine if satisfaction differs for the two housing types.

4 WHOLE HOUSE ENERGY TESTS

Three whole house energy tests were performed on a sample of units from each type of construction. Appendices C and D give details.

House Tightness

The number of air changes per hour were measured with the following results:

Type	No. Units	Average	Standard Deviation
CBU	15	13.0	1.06
MHU	12	10.9	2.67

There is a statistically significant difference between the two types of construction, with the MHU being more airtight on the average.

Furnace Efficiency

The furnace efficiency results were as follows:

Type	No. Units	Average	Standard Deviation
CBU	13	66.2%	6.24%
MHU	16	79.3%	3.36%

The furnace efficiencies of the MHU were significantly higher than those of the CBU.

Wall Heat Transfer Characteristics

This parameter was not measured for the CBU because of unfavorable weather. This parameter was *calculated* for both types of construction using the designed wall construction. These data are given in Appendices C and D and are summarized below:

Type	No. Units	Average (Btu/hr–°F)	Standard Deviation (Btu/hr–°F)
CBU	16	310	51
MHU	15	237	58

5 O&M COSTS

Overall Costs

The total housing unit-months and maintenance costs through September 1984 are shown below:

Type	No. Months	Total Cost ($)	Cost/ Month ($)	Cost/ Year ($)
MHU	1420	11874	8.36	100
CBU	2527	35100	13.89	167

The MHU have not been through a complete heating season yet, and their costs may increase over the coming winter season.

Frequencies of Maintenance Per Housing Unit

For the MHU the number of service orders for a housing unit ranges from 0 to 21. For the CBU the range is 0 to 32. Table 1 lists the frequencies.

Frequencies of Maintenance Per Component

Table 2 lists the frequencies of service orders per building component, where the frequency is at least 2 percent of the total number of service orders.

6 ENERGY COSTS

Comparisons of gas and electricity consumption began in April 1984, since most MHU were not occupied before then.

Table 1

Frequency of Repair
(CBU vs. MHU)

Conventionally Built Units		Manufactured Housing Units	
No. of Service Calls	No. of Units With These Totals	No. of Service Calls	No. of Units With These Totals
32	1	21	1
25	1	15	3
23	1	14	1
22	1	13	1
21	1	12	2
19	2	11	3
18	3	10	5
17	3	9	8
16	6	8	8
15	2	7	11
14	4	6	16
13	5	5	23
12	7	4	18
11	8	3	26
10	6	2	29
9	7	1	24
8	14	0	23
7	16		
6	9		
5	15		
4	13		
3	12		
2	5		
1	5		
0	1		

Electricity Consumption

The average usage (kWh) per housing unit is shown below:

	MHU	CBU
Apr	417	418
May	780	704
Jun	1007	966
Jul	1220	1170
Aug	1272	1139
Sep	1015	1004

For the 6-month period, an MHU used an average total of 5942 kWh while a CBU used an average of 5405 kWh.

Gas Consumption

The average usage (100 cu ft) per housing unit is shown below:

	MHU	CBU
Apr	174	145
May	90	71
Jun	68	64
Jul	57	53
Aug	62	60
Sep	58	55

For the 6-month period, an MHU used an average total of 475 cu ft while a CBU used an average of 450 cu ft.

Table 2

Maintenance Per Component
(Percent of Service Calls by Component)

Component No.	Description	Conventional Housing Units (N=1264)*	Manufactured Housing Units (N=856)
0104	Gutters and Downspouts	29 (2%)	**
0206	Exterior Doors and Frames	91 (7%)	48 (6%)
0207	Storm and Screen Doors	27 (2%)	--
0208	Windows and Frames		20 (2%)
0212	Interior Drywall	19 (2%)	13 (2%)
0214	Interior Doors	70 (6%)	39 (5%)
0215	Interior Casework	--	21 (2%)
0220	Garage Door	38 (3%)	--
0301	Resilient Flooring	--	26 (3%)
0601	Heating Plant	66 (5%)	--
0607	Heating Controls	44 (3%)	--
0608	Other Heating	25 (2%)	--
0701	Cooling Coils	--	17 (2%)
0702	A/C Motors, Blowers, Pumps	21 (2%)	14 (2%)
0704	A/C Refrigerant	74 (6%)	20 (2%)
0706	A/C Controls	24 (2%)	17 (2%)
0707	A/C Other Cooling	41 (3%)	48 (6%)
0801	Water Heater	28 (2%)	25 (3%)
0803	Piping, Supply	35 (3%)	41 (5%)
0804	Faucets and Shower Heads	31(2%)	42 (5%)
0805	Lavatories	25 (2%)	--
0806	Water Closets	52 (4%)	33 (4%)
0807	Bathtub/Shower Unit		19 (2%)
0902	Panel Box		17 (2%)
0904	Wall Receptacles	19 (2%)	25 (3%)
0906	Light Fixtures	50 (4%)	--
1001	Garbage Disposal	49 (4%)	31 (4%)
1002	Dishwasher	40 (3%)	44 (5%)
1003	Range	92 (7%)	83 (10%)
1201	Water Supply	35 (3%)	35 (4%)

*N = Number of Service Orders

** = Less than 2%

7 OCCUPANT SATISFACTION

One part of the study assesses occupants' satisfaction with their housing. Use of lower cost housing would be questionable if it created morale problems with Army personnel. A questionnaire developed at USA-CERL and approved by FORSCOM, FESA, and OCE is given in Appendix F.

A copy of the questionnaire with a mail-back envelope (to USA-CERL) is given to each vacating family by BSI approximately 2 weeks before vacating. BSI is also to check with the family when they are vacating to encourage completion and mail-back.

Through September 1984, the return rate on the questionnaires was 35 percent. This response rate is considered low. A special survey was done of all 78 families who have lived in their CBU quarters at least 1 year. Of these, 25 (32.1 percent) returned questionnaires. A similar survey on MHU will be done in 1985.

Because of the small number of responses to date (49 for CBU and 15 for MHU), no summary was made at this time.

3 CONCLUSION

Data collection procedures were set up to collect ll maintenance and energy use costs for the test units. he procedures are working well. Data were validated nd summarized through September 1984.

Whole house energy tests were performed on a ample of each type construction.

Maintenance costs were collected, and gas and lectricity consumption data were also collected.

Response rate of the vacating occupants to questionnaires about their satisfaction with the units is low and these personnel will be encouraged to return the completed questionnaire.

METRIC CONVERSION TABLE

°F	=	9/5°C +32
therm	=	100,000 Btu
1 in. water (60°F)	=	.07355 cm of mercury (60°F)
Btu/hr	=	1.055×10^{3} joule/hr
ft^2	=	$9.290 \times 10^{-2} m^2$

8. Did any of the items listed in question 7 require repair?

_____Yes _____No 22

If No, skip to question 9.

If Yes, were repairs accomplished by _____Occupant _____FE/Contractor 23

Briefly describe occurrences (if self help, was it easy in comparison to other gov't quarters?, etc.)_____

_____

_____

9. Is there another set of quarters above you? _____Yes _____No 24

If No, skip to question 10.

If Yes:

has noise from it ever annoyed you and/or your family? _____Yes _____No 25

have odors from it ever annoyed you and/or your family? _____Yes _____No 26

10. Is there another set of quarters below or adjoining yours? _____Yes _____No 27

If No, skip to question 11.

If Yes:

has noise from it ever annoyed you and/or your family? _____Yes _____No 28

have odors from it ever annoyed you and/or your family? _____Yes _____No 29

11. Is the floor plan of your quarters satisfactory? _____Yes _____No 30

If No, please explain_____

_____

_____

12. Has your air conditioning been satisfactory? _____Yes _____No 31

If No, please explain_____

_____

_____

13. Has your heating been satisfactory? _____Yes _____No 32 sk 33

If No, please explain_____

_____

_____

7. For each item below, please check the appropriate answer for the questions.

	In general, are you satisfied with the item?			Is the item		
	Satisfied	Not Satisfied	No Opinion	Hard to Clean	Easy To Clean	No Opinion
a. Bathroom floor	____ 49	____	____	____	____	____ 50
b. Bathroom tubs and showers	____ 51	____	____	____	____	____ 52
c. Bathroom sink and faucets	____ 53	____	____	____	____	____ 54
d. Kitchen floor	____ 55	____	____	____	____	____ 56
e. Kitchen cabinets	____ 57	____	____	____	____	____ 58
f. Kitchen sink and faucets	____ 60	____	____	____	____	____ sk 59 61
g. Range/ oven	____ 62	____	____	____	____	____ 63
h. Refrigerator	____ 64	____	____	____	____	____ 65
i. Dishwasher	____ 66	____	____	____	____	____ 67
j. Living/Dining room floors	____ 68	____	____	____	____	____ sk 69 70
k. Bedroom floors	____ 71	____	____	____	____	____ 72
l. Doorknobs and locks	____ 73	____	____	____	____	____ 74
m. Interior walls	____ 75	____	____	____	____	____ 76
n. Electric outlets/ switches	____ 77	____	____	____	____	____ 78 sk 79
o. Light fixtures	____ /	____	____	____	____	____ 80 cd 1 dup 1-5 8 sk 6
p. Windows	____ 9	____	____	____	____	____ 10
q. Doors	____ 11	____	____	____	____	____ 12
r. Garage	____ 13	____	____	____	____	____ 14
s. Closet/interior storage space	____ 15	____	____	____	____	____ 16
t. Exterior storage space	____ 17	____	____	____	____	____ 18
u. Kitchen and bath exhausts	____ 19	____	____	____	____	____ 20 sk 21

Any comments on above? _____

_____

APPENDIX F:
USER SATISFACTION QUESTIONNAIRE

Quarters No:_____ 1-5 sk 6
Date:_____ 7-12 sk 13

HOUSING SATISFACTION QUESTIONNAIRE FOR RESIDENTS OF NEW HOUSING

This questionnaire is designed to assist the Director of Engineering and Housing in evaluating the new housing you are occupying. Your careful completion of this questionnaire will help us to continue to improve new Army family housing. Please mail the questionnaire in the attached envelope.

1. How many total years have you lived in military family housing? _____years 14-16

2. Please identify the different types of quarters you have lived in during these years.

_____detached dwelling unit (house)

_____duplex (two units)

_____multi-level, three or more families 17

_____single-level, three or more families

3. How long have you occupied these new quarters?
_____years _____months 18-19 sk 20

4. List all family members (include yourself) who occupy these quarters, including sex and ages (do not list by name).

	Relationship	Sex	Age
a.	_____ 21	___ 22	___ 23-24 sk 25
b.	_____ 26	___ 27	___ 28-29 sk 30
c.	_____ 31	___ 32	___ 33-34 sk 35
d.	_____ 36	___ 37	___ 38-39 sk 40
e.	_____ 41	___ 42	___ 43-44 sk 45

5. How would you rate the condition of your quarters? (Circle one)

a. Excellent
b. Better than average
c. Average 46
d. Below average
e. Poor

6. In general, how satisfied have you been with these quarters? (Circle one)

a. Very satisfied
b. Satisfied 47
c. Dissatisfied
d. Very Dissatisfied sk 48

10 EQUIPMENT

1001 Disposal
1002 Dishwasher
1003 Stove, Range
1004 Range Hood
1005 Refrigerator
1006 Other Equipment

11 UTILITY PLANT EQUIPMENT

Not Applicable

12 UTILITY SERVICE

1201 Water Supply
1202 Gas Supply
1203 Electrical Service
1204 Sanitary/Sewer
1205 Other Utility Service

13 MISCELLANEOUS

APPENDIX E: BUILDING COMPONENTS/ SUBCOMPONENTS

01 ROOFING

0101 Roofing Surface
0102 Fasteners
0103 Flashing, Vents, Protrusions
0104 Gutters and Downspouts
0105 Other Roof Repair

02 STRUCTURE

0201 Foundation and Anchorage
0202 Structure, Incl. Framing and Sheathing, Stairs
0203 Insulation and Moisture Protection
0204 Masonry
0205 Exterior Siding, Incl. Skirting
0206 Exterior Doors and Frames, Incl. Hardware and Weatherstripping
0207 Storm and Screen Doors
0208 Windows and Frames, Incl. Hardware and Weatherstripping
0209 Stormwindows and Screens
0210 Exterior Trim
0211 Porch/Deck Construction
0212 Interior Drywall, Incl. Fasteners and Accessories
0213 Wall Coverings and Paneling
0214 Interior Doors, Frames, and Hardware, Incl. Bi-Fold and Sliding
0215 Interior Casework and Finish Carpentry
0216 Bathroom Accessories
0217 Kitchen Accessories
0218 Drapery Hardware
0219 Other Exterior/Interior Repair
0220 Garage Door

03 FLOOR COVERINGS

0301 Resilient Flooring
0302 Carpet and Pad
0303 Ceramic Flooring
0304 Underlayment/Substrate
0305 Other Flooring Repairs

04 INTERIOR PAINTING

0401 Walls and Ceilings, Incl. Patching
0402 Trim
0403 Touch-Up
0404 Bathtub/Shower Unit Calking
0405 Other Interior Painting

05 EXTERIOR PAINTING

0501 Walls, Siding, Incl. Skirting
0502 Doors, Frames, Trim
0503 Exterior Trim, Incl. Window, Fascia, Rake, Soffit, Etc.
0504 Calking and Sealing
0505 Glazing
0506 Other Exterior Painting

06 HEATING

0601 Heating Plant
0602 Motors, Blowers, Pumps
0603 Ducts
0604 Piping
0605 Diffusers, Grilles
0606 Insulation
0607 Heating Controls
0608 Other Heating Repairs

07 AIR CONDITIONING

0701 Cooling Coils, Compressor, Condenser
0702 Motors, Blowers, Pumps
0703 Piping
0704 Refrigerant
0705 Insulation
0706 Controls
0707 Other Cooling Repairs

08 PUMPING

0801 Water Heater
0802 Water Softener
0803 Piping, Supply, Incl. Valves, Arrestors
0804 Faucets and Shower Heads
0805 Lavatories, Incl. Support and Fasteners
0806 Water Closets (i.e., toilets/commodes), Including Supports and Seals
0807 Bathtub/Shower Unit
0808 None
0809 Other Plumbing Repair

09 ELECTRICAL

0901 Service Entrance
0902 Panel Box, Incl. Circuit Breakers
0903 Branch Circuits, Incl. Junctions, Fasteners
0904 Wall Receptacles and Switches
0905 Doorbells, Chimes
0906 Light Fixtures
0907 Vents, Fans
0908 Other Electrical Repair

Furnace Efficiency

The furnaces in all of the units were propane-fired. Tests were performed using a Fuel Efficiency Monitor (FEM), as described in Appendix C. A carbon monoxide meter similar to the FEM was used to insure that each furnace's burner was completely combusting its fuel and there was no unusual concentration of carbon monoxide.

The testing was performed in the early morning hours so there would be a low outdoor temperature to start the furnace. The safety relief on the front of each furnace was taped over to prevent room air from entering the flue. A 1/8-in. hole was drilled into the flue near the furnace. The furnace was turned on and a sample of the ambient air was taken. The furnace was then left to reach steady state (approximately 15 min) and then the FEM probe was inserted into the hole and a sample of the exhaust gas was taken. The FEM took approximately 2 to 3 min to calculate and display the efficiency. Three samples were taken to insure furnace steady state. The hole in the flue was then taped closed.

The furnace efficiencies are typical for the size and type of furnace installed.

A serious problem was found during the furnace testing for Type I Units 3809, A and D. The gas was burning in the mixing manifold before it got to the burner. This is extremely dangerous and was reported immediately to responsible Fort Irwin personnel.

Wall Heat Transfer Characteristics

A Thermo Flow Energy Meter (TEM), as described in Appendix C, was used to test the heat transfer characteristics of the exterior walls of each unit. It was also used to detect insulation defects.

This testing was done in the early morning hours because a constant temperature difference of at least 20°F must exit between outdoor and indoor temperatures. First the outdoor and indoor temperatures were taken until they appeared steady, then the TEM was aimed at an interior wall and the net heat flow reading was recorded. Then the TEM was aimed at an exterior wall and the heat flow through the wall was recorded. Then the same measurement was made on the outside of the exterior wall (being sure that the area was shaded from sunlight). These results were used in conjunction with a standardized chart to determine the wall's thermal resistance. After these measurements were taken, the TEM was used to detect areas of abnormally high net flow readings, which indicate areas of insulation defects. There appear to be a number of insulation voids in Type I, II, and IV Units.

The UA values were calculated for the units, representing the overall heat transfer for the unit inclusive of walls, windows, doors, and roof (heat transferred from one unit to the next unit was considered negligible). The insulation voids listed in Table D2 were determined when the net heat flow varied by 10 Btu/hr–°F.

Table D2

Insulation Void Locations

Building/Unit	Location of Void
3802A	Void area at upper left corner of window in front bedroom.
3802C	Void area above sliding glass door in dining room.
3802D	Void area at right electrical outlet in dining room.
3806C	Void areas in all wall-to-wall seams (corners).
3806D	Void areas in all wall-to-wall seams (corners).
3809B	Void area at upper right corner of sliding glass door in dining room.

APPENDIX D: ENERGY EFFICIENCY TESTS OF 16 MANUFACTURED HOUSING UNITS AT FORT IRWIN, CA

The objective of these tests was to provide data on the energy efficiency of manufactured housing units which will be compared to existing energy efficiency data taken on conventionally built housing units. Tests were performed to determine the airtightness of the units (a measure of the resistance to air infiltration), furnace efficiencies, and heat transfer characteristics of the building envelope.

Tests were conducted on three types of fourplexes; Type I (Building 3809), II (Building 3802), and IV (Buildings 3800 and 3806). The tests were conducted over 4 days in April 1984. The weather during the testing was mild for high desert area: medium to strong winds, overcast skies, low humidity, and temperatures ranging from morning lows of 40°F to highs near 80°F.

House Tightness

To measure the tightness of each housing unit a blower door apparatus was used, as described in Appendix C.

Each of the manufactured housing units was tested at 0.1, 0.2, and 0.3 in. of water during pressurization and then tested at 0.1 and 0.2 in. under depressurization. Then some of the obvious leaks were taped (furnace doors and kitchen vents) and the unit was retested at 0.2 in. during pressurization and depressurization. During the final day the winds were gusting so high that no consistent manometer reading could be taken, so Building 3809 has no data for air infiltration.

The results of the USA-CERL testing, as presented in Table D 1, demonstrate that the airtightness of all the units except one is acceptable. Unit 3800-C has a significantly higher value than the other units and should have corrective work done to improve its tightness.

Also during the airtightness testing several leaks were found. In Type II, Unit 3801-C, serious leaks were found in the door to the furnace room. In Type IV, Units 3800 and 3806, leaks were found while depressurizing around the furnace vents and doors (Unit A in both buildings). Also, leaks were found around sliding doors (Unit 3800-C), kitchen window area (Unit 3806-D), utility outlets (Unit 3800-D), and a crack in the dining room wall (Unit 3806-D).

Table D1

MHU Energy Efficiency Data

Building/Unit	UA* (Btu/hr-°F)	Air Changes Per Hour	Furnace Efficiency
3800A	296	9.9	75.5%
3800B	296	11.5	81.8%
3800C	363	18.4	80.5%
3800D	363	11.3	82.6%
3802A	271	9.0	70.1%
3802B	271	10.1	75.1%
3802C	370	12.1	81.8%
3802D	370	11.3	80.3%
3806A	296	8.0	78.2%
3806B	296	9.8	77.4%
3806C	363	8.7	80.7%
3806D	363	10.6	82.2%
3809A	249	**	80.9%
3809B	249	**	82.0%
3809C	336	**	80.7%
3809D	336	**	79.6%

*These are calculated based on the wall construction. U = heat transfer coefficient; A = area.

**Unable to test airtightness due to high winds.

Table C1

CBU Energy Efficiency Data

Building/Unit	UA* Btu/hr–°F	Air Changes** Per Hour	Furnace*** Efficiency
3720 A	213	11.4	52.6%
3720 B	181	12.1	61.3%
3720 C	181	13.1	62.8%
3720 D	213	12.8	67.2%
3720 E	304	12.4	71.7%
3720 F	304	13.2	73.0%
3724 A	181	11.8	61.9%
3724 B	181	13.3	62.6%
3724 C	304	13.0	71.4%
3724 D	304	15.1	72.3%
3725 A	181	11.7	61.6%
3725 B	181	12.8	****
3725 C	213	13.9	69.3%
3725 D	304	13.4	72.7%
3725 E	304	14.8	****

*These are calculated values based on the wall construction. U = heat transfer coefficient; A = area.

**The following rating of air changes per hour at 0.2 in. w.c. is based on work currently being done by Mansville Corp. for the U.S. Navy: 0 to 5, objectionably tight; 5 to 10, excellent; 10 to 15, satisfactory; 15 and above, merits corrective work.

***Most gas fired furnace manufacturers claim 80 percent efficiency.

****Unable to test furnace.

APPENDIX C: ENERGY EFFICIENCY TESTS OF 15 CONVENTIONALLY BUILT HOUSING UNITS AT FORT IRWIN, CA

The objective of these tests was to provide data concerning the energy efficiency of conventionally built housing. Tests were performed to determine the airtightness of the units (a measure of the resistance to air infiltration), furnace efficiencies, and heat transfer characteristics of the building envelope.

Tests were conducted over four days in June 1983 on three types of buildings: a fourplex, a fiveplex, and a sixplex. Weather conditions were typical of the high desert area: light to negligible winds, clear skies, low humidity, and temperatures ranging from lows near 70°F to highs near 110°F.

House Tightness

A blower door apparatus was used to measure each unit's tightness. The blower door consists of a variable-speed fan, a digital tachometer to measure the fan blade rotation speed, and an inclined manometer to measure pressure differences. The fan can be operated to induce a positive or negative pressure difference in the house with respect to the outdoors.

To perform this test, the fan is fitted tightly into an outside door frame. A barbed fitting which penetrates the blower door is fitted with rubber tubing and connected to one side of the manometer. The other side of the manometer is open to the house. When the fan is operated, it can either force air into the house (pressurized) or force air out of the house (depressurized) depending on the direction of rotation. In either case, the pressure difference between the house and the outdoors can be read on the manometer. The fan speed is adjusted until a specified pressure difference exists (usually 0.1 or 0.2 in. of water). The fan speed required to achieve a given pressure is correlated to air flow, which indicates how tightly the house is sealed.

At Fort Irwin, each of the units was tested at 0.1 and 0.2 in. H_2O pressurized, and 0.2 in. H_2O depressurized. Some of the more obvious leaks (furnace room doors, dryer vents, attic doors) were then taped, and the house was again tested at 0.2 in. H_2O depressurized.

As shown in Table C1, airtightness was adequate, requiring no corrective work.

Furnace Efficiency

The furnaces in all the units were propane-fired. Tests were performed with a Fuel Efficiency Monitor (FEM), a hand-held automatic flue gas analyzer which measures the flue gas temperature, oxygen content, and ambient conditions and uses this information to calculate and display the percent efficiency of the furnace.

Each housing unit was first cooled down to 70° to 80°F using the air conditioning system. The thermostats in the houses are of the "energy-saving" type, and include night setback and temperature limits. These were disconnected before each test so that the heating and air conditioning could be manually adjusted. The safety relief on the front of each furnace was covered so that room air would not be introduced into the flue. The furnace was then turned on, and a sample was taken of the intake air using the FEM. A 1/8-in. hole was then drilled in the flue of the furnace. After allowing a few minutes for the furnace to reach steady state, the FEM probe was inserted into the flue pipe and a sample was taken of the exhaust gas. The FEM took 2 to 3 min to calculate the furnace efficiency.

Table C1 shows the furnaces' operational efficiencies.

Wall Heat Transfer Characteristics

A Thermo Flow Energy Meter (TEM) was obtained to test the heat transfer characteristics of the walls. The TEM is an infrared radiometer which displays heat flow digitally in units of Btu/hr/sq ft. It can be used to detect insulation defects and to estimate the thermal resistance of exterior walls.

Due to unfavorable weather, the TEM could not be used to calculate R-values. The device is also useful for detecting insulation voids. No insulation voids were found.

RECORD OF MAINTENANCE AND REPAIR

Housing Unit No.	Type Document	Date of Document Mo Day Yr	Document Number	Building Component	Description of Work	Labor Craft Code	Labor No. Manhours	Labor Cost	Materials Cost	Equipment Bumper No.	Equipment Hours	Equipment Cost	Total Cost Of Job

GAS AND ELECTRIC METER READINGS

Housing Unit	Date Mo Day Yr	Gas Meter	Electricity Meter
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		
	/ /		

SELF HELP DATA

Housing Unit Number	Date Mo Day Yr	Description of Item Issued	Cost

APPENDIX B:
DATA COLLECTION FORMS

OCCUPANCY DATA

Housing Unit	Date of Occupancy Mo Day Yr	Date of Vacancy Mo Day Yr	For Incoming Occupants Rank	Number of Occupants	Ages of Occupants

APPENDIX A:
LIST OF HOUSING UNITS

Conventionally Built

3680 A-F	3705 A-E	3727 A-E
3681 A-D	3712 A-F	3731 A-D
3684 A-D	3715 A-F	3732 A-F
3685 A-F	3720 A-F	3738 A-F
3690 A-F	3721 A-E	3742 A-D
3691 A-D	3722 A-E	3743 A-F
3693 A-F	3723 A-E	3745 A-F
3694 A-D	3724 A-D	3737 A-D
3695 A-D	3724 A-E	3750 A-F
3700 A-F		

Manufactured (Each with four apartments, A-D)

3800	3821	3841
3801	3822	3842
3802	3823	3843
3803	3824	3844
3804	3825	3845
3805	3826	3846
3806	3827	3848
3807	3828	3850
3809	3829	3851
3811	3831	3852
3812	3832	3853
3813	3833	3854
3814	3834	3855
3815	3835	3856
3816	3837	3857
3818	3839	3858
3820	3840	

14. In general, how satisfied are you with:

	Very Satisfied	Satisfied	Dissatisfied	Very Dissatisfied	
a. The exterior of your building	____	____	____	____	34
b. Front/rear yards and play areas	____	____	____	____	35
c. The housing complex	____	____	____	____	36
d. Parking facilities	____	____	____	____	37

sk38

15. Please list three things about your apartment you <u>like most</u>.

_____ 39-40

_____ 41-42

_____ 43-44

sk45

16. Please list three things about your apartment you <u>do not like</u>.

_____ 46-47

_____ 48-49

_____ 50-51

sk52

17. Please make any general comments about your apartment.

_____ 53-54

_____ 55-56

_____ 57-58

sk59-79

80 CD2

THANK YOU VERY MUCH FOR YOUR COOPERATION

DISTRIBUTION

Chief of Engineers
ATTN: DAEN-ACH-F (10)
ATTN: DAEN-ASI-L (2)
ATTN: DAEN-EC
ATTN: DAEN-ECC
ATTN: DAEN-ECE
ATTN: DAEN-ECR
ATTN: DAEN-RD
ATTN: DAEN-RDC
ATTN: DAEN-RDM
ATTN: DAEN-RM
ATTN: DAEN-ZCE
ATTN: DAEN-ZCF
ATTN: DAEN-ZCI
ATTN: DAEN-ZCM
ATTN: DAEN-ZCZ

FESA, ATTN: Library 22060
ATTN: DET III 79906

U.S. Army FESA
ATTN: FESA-EB (2)

U.S. Army Engineer Districts
ATTN: Library (41)

Commander
U.S. Army Engineer District,
Los Angeles
ATTN: SPLCO-CM (2)

U.S. Army Engineer Divisions
ATTN: Library (14)

Commander
U.S. Army Engineer Division,
South Pacific
ATTN: SPDED (2)

TRADOC
HQ, TRADOC, ATTN: ATEN-DEH
ATTN: DEH (19)

FORSCOM
FORSCOM Engr, ATTN: AFEN-DEH
ATTN: DEH (23)

Commander
U.S. Army Forces Command
ATTN: AFEN-RMO (2)

Commander
National Training Center
ATTN: AFZJ-FER (2)

U.S. Army Corps of Engineers
Ft. Irwin Office (2)

U.S. Army Europe
ATTN: C/AEAEN-EH-H

NCEL ATTN: Library, Code L08A 93041

Defense Technical Info. Center 22314
ATTN: DDA (12)

END

FILMED

11-85

DTIC